Appendix A

Ecological Management Decision Support (EMDS): The NCWAP Watershed Condition and Stream Reach Condition Models

I. Ecological Management Decision Support (EMDS): A NCWAP tool for Data Analysis and Synthesis

Introduction

NCWAP has chosen to use the Ecological Management Decision Support system model (EMDS) (Reynolds 1999) to help us evaluate and synthesize information on watershed and stream conditions for salmonids (note that it does not address other factors such as marine habitat and fishing). EMDS is an indicative model that helps to synthesize and explore a wide range of data. That is, it indicates what the quality of watershed or instream conditions are, based on available data and the model structure. It is not a highly rigorous process or statistical model intended to provide outputs with a known level of accuracy. Thus, we use EMDS as one tool, in conjunction with other information and analyses, to help identify the habitat factors that that are limiting the production of salmonids on North Coast Watersheds (see limiting factors discussion, above). To the extent possible, EMDS outputs should be compared to direct measures of salmonid production—i.e., the number of salmonids found in streams. While this section of the report describes in general how the EMDS model works, the basin profile, subbasin analyses, and EMDS Appendix of this report present the findings from running the model on Redwood Creek, as well as more details about the model itself.

EMDS has a number of advantages for the assessment work NCWAP is conducting. First, rather than being an obscure "black box" model, EMDS has an explicit and intuitively understandable model structure. EMDS models can be easily modified to incorporate different data sets or different assumptions about what specific levels of specific factors (e.g., stream water temperature) are needed to provide suitable salmonid habitat. Further, since it is a spatial model, it can help us to understand how factors interact across a watershed to affect habitat. Therefore, its map-based outputs can clearly communicate model results. Finally, while the model produces a useful, overall watershed condition rating, highly specific information about the individual factors determining that overall condition can be gleaned from looking at the particular, supporting levels of the model. This specificity can help to identify those factors that are most limiting salmonid habitat and thus in most need of attention through restoration or modification of land use activities.

In using the outputs of EMDS, it should be cautioned that expectations that all factors for salmonids in a watershed should be fully suitable for salmon at all times are unrealistic. Watersheds, subwatersheds, and streams intrinsically vary in their suitability for salmonids. Natural geologic, climatic, vegetation, and other factors can mean that some areas will never be suitable for salmon.

While EMDS has many advantages, the EMDS model we have developed and the data we are using to run it nonetheless have limitations. A section below documents these limitations. Note that the version of the EMDS model used in this report is preliminary. A scientist and resource professional review team is being empanelled, with help from the University of California, Berkeley, to help us strengthen the model. This revised model should be ready in time to utilize in the final draft of this report, which we expect to complete May 2002.

Details of the EMDS Model

EMDS is a "knowledge base" or "expert" system computer model. The knowledge base modeling software of EMDS requires scientists to identify and evaluate specific environmental factors or attributes, such as stream temperature and land use activities, which contribute to the formation of anadromous salmonid habitat. As such, EMDS provides a consistent and repeatable approach to evaluating conditions across watersheds. The spatial nature of EMDS makes it particularly useful for evaluating and portraying watershed and stream conditions.

This model employs a linked set of software that includes MS Excel, NetWeaver, Ecological Management Decision Support (EMDS) and ArcView™. Microsoft Excel is a commonly used spreadsheet program for data storage and analysis. NetWeaver (Saunders and Miller (no date)), developed at Pennsylvania State University, helps scientists build graphics of networks that specify how the various environmental factors are incorporated into an overall stream or watershed assessment. These networks resemble branching tree-like flow charts, and graphically show the logic and assumptions used in the synthesis.

EMDS (Reynolds 1999), was developed by Dr. Keith Reynolds at the USDA-Forest Service, Pacific Northwest Research Station. It uses the networks created with NetWeaver in conjunction with environmental data stored in a geographic information system (ArcView™) to perform the assessments and facilitate rendering the results into maps. This combination of Excel/NetWeaver/EMDS/ArcView software is currently being used for watershed assessment within the federal lands included in the Northwest Forest Plan.

NCWAP's development of its EMDS model began with a multi-day workshop organized by the University of California, Berkeley. In addition to NCWAP staff, the workshop involved model developer Keith Reynolds and several scientists. As a starting point, NCWAP used the EMDS knowledge base developed for use in coastal Oregon. Based on the workshop, subsequent discussions among NCWAP staff and scientists, examination of the literature, and consideration of California conditions, NCWAP developed its preliminary 1.1 version of the EMDS model, which is used in this report. As noted above, with further assistance from UC Berkeley, a team of scientists and resource professionals will review this preliminary model version and the data sets used in it. NCWAP will then revise the model accordingly.

The Knowledge Base Network

For California's north coastal watersheds, the NCWAP team built two knowledge base networks using the best available scientific studies and information on how various environmental factors combine to affect anadromous fish on the north coast. The first, called the Stream Reach model (Figure 2), addresses conditions for salmon on individual stream reaches and is largely based on data collected under the Department of Fish and Game's stream survey protocols. The second, the Watershed Condition model (Figure 3), serves as a framework for synthesis by watershed of a number of environmental factors in riparian and upland areas.

In creating both of these networks, the NCWAP scientists have used what is termed a 'top-down' approach. This approach is perhaps best explained by way of example. The model starts from the proposition that *the overall condition of a given watershed is suitable for maintaining healthy populations of native coho and chinook salmon, and steelhead trout*, and through the design of the knowledge base (the network) seek to evaluate the 'truth' of that assertion. We then constructed a knowledge base network to specify the types of information needed to test the proposition. That information focuses on the current condition of the many factors affecting salmonids, their streams, and watershed processes.

The "ingredients," or data, needed for the assessment are broken down into categories. To evaluate watershed conditions for salmonids, the model requires data on several general environmental factors. The first branches of the knowledge base network (Figure 1) show that information on upland condition, roads, passage barriers, and stream condition factors are all needed in the watershed assessment. The "AND" decision node (where the factors are combined) means that each of the four general factors must be suitable for the fish for the "watershed is suitable for native salmonids" proposition to be evaluated as completely "true."

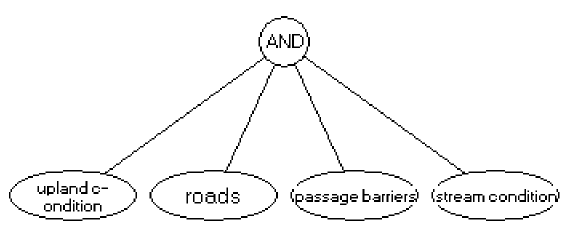

Figure 1: EMDS Knowledge Base Network.

EMDS uses knowledge base networks to assess the condition of watershed factors affecting native salmonids.

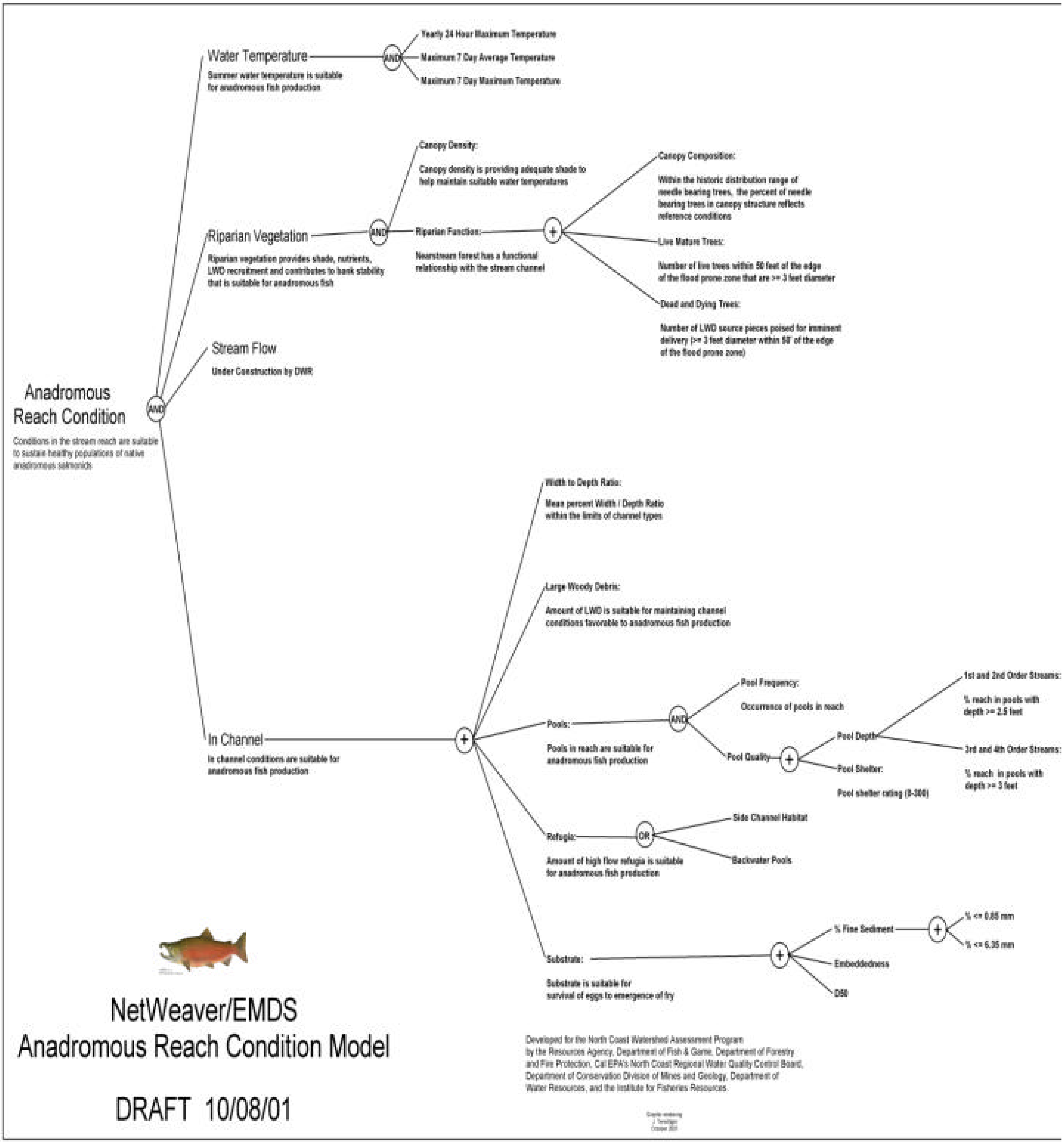

Figure 2: NCWAP EMDS Reach Condition Model.

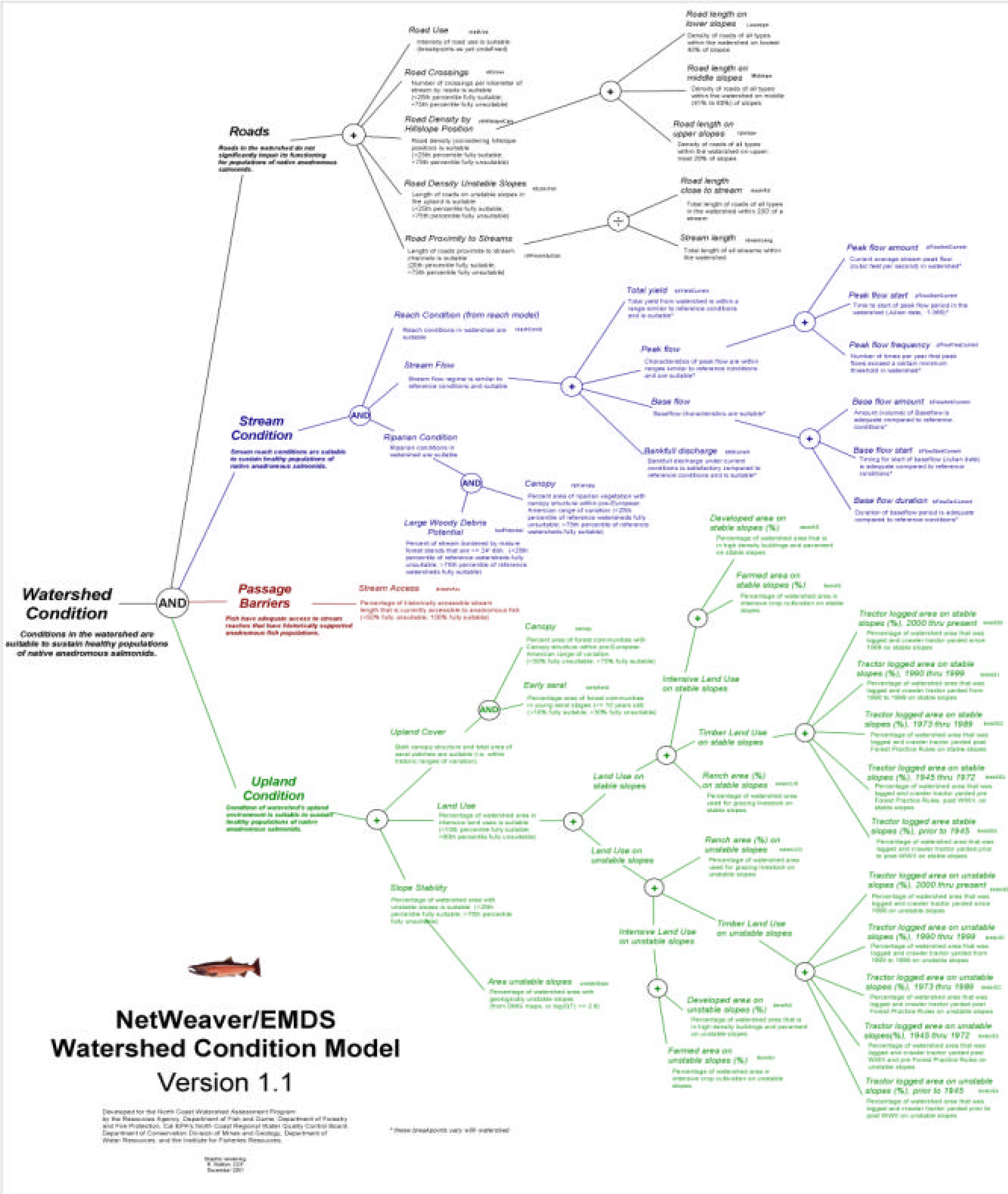

Figure 3: NCWAP EMDS Watershed Condition Model.

Each of the elliptical boxes in Figure 1 shows a factor used in the assessment, and lines indicate how they are linked to the 'AND' node, where they are compared. In a similar manner, each of the factors can be broken down into the more basic data components that determine it (See Figures 2 and 3). For example, in the NCWAP Watershed Condition model the 'upland condition' factor consists of a subnetwork of more detailed data on land use, land cover (vegetation) and slope stability that determine it. Information in the subnetwork that determines land use includes data on developed area, cultivated area, grazed area and area of timber harvests. While the overall watershed condition rating output of the EMDS model is useful to get a rough understanding of the condition of the entire basin, its subbasins, watersheds or subwatersheds, perhaps the most important part of the model is the more specific information about factors affecting fish that can be gleaned by looking at the finer scales of the dependency networks that contribute to the model's conclusions.

Wherever there is a proposition in the network, scientists use simple graphs, called "reference curves," that determine its degree of truth, according to the data and its implications for salmon. Figure 4 shows an example reference curve, where the proposition is "*the stream temperature is suitable for salmon*". The horizontal axis shows temperature in degrees Fahrenheit, while the vertical is labeled 'Truth Value' and ranges from –1 to +1. The line shows what are fully unsuitable temperatures (-1), fully suitable temperatures (+1) and those that are in-between (> -1 and <+1). In this way, similar numeric relations are hypothesized for all propositions in the EMDS evaluation.

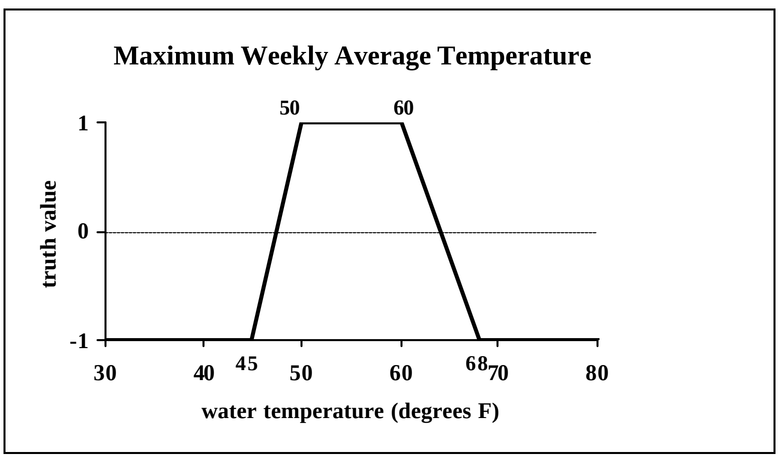

Figure 4: EMDS Reference Curve.

EMDS uses this type of reference curve in conjunction with data specific to a stream reach. This example curve tests the proposition that the stream's water temperature is suitable for salmonids. Break points can be set for specific species, life stage, or season of the year. Curves are dependent upon the availability of data.

For all evaluated propositions in the network, the results are a number between –1 and +1. The number shows the degree to which the data support or refute the 'conditions are suitable' proposition. In all cases a value of +1 means that the proposition is 'completely true', and –1 implies that it is 'completely false', with in-between values indicate 'degrees of truth' (i.e. values approaching +1 being closer to true and those approaching –1 converging on completely untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints (where the slope of the function changes) in the Figure 4 example occur at 45, 50, 60 and 68 degrees F. The NCWAP fisheries biologists determined these temperatures by a search of the scientific literature.

We use the following classification system to verbally describe the EMDS truth-values of watershed and stream conditions for salmonids:

Truth Value	Habitat Component(s) Condition for Salmon
1 (completely true)	fully suitable
1 to 0.5	moderately suitable
0.5 to 0	somewhat suitable
0	undetermined (no data)
0 to -0.5	somewhat unsuitable
-0.5 to -1	moderately unsuitable
-1 (completely false)	fully unsuitable

In EMDS, the data that are fed in to the knowledge base network come from GIS layers stored and displayed in ArcView. Thus many of the GIS data layers developed for the program will be used directly in the watershed condition syntheses. The results can easily be portrayed on maps (Figure 5).

Reference Curves used in NCWAP's Preliminary EMDS Model

Tables EMDS 1 and 2 document the reference curves used in our preliminary EMDS watershed and stream reach models to evaluate conditions for salmonids. In some cases, the reference curves were established on a relative basis (e.g., percentiles of a data range) due to the lack of a scientific or expert judgement basis, rather than using absolute values (e.g., a stream temperature of 45º F). These reference curves, in addition to the overall structure and content of the model, will be carefully reviewed by the scientist and resource professional review team.

Advantages Offered by NetWeaver/EMDS/ArcView Software

The NetWeaver/EMDS/ArcView software offers a number of advantages for use in the NCWAP. At this time no other widely available package allows a knowledge base network to be linked directly with a geographic information system such as ArcView. This link is vital to the production of maps and other graphics reporting the watershed assessments.

The graphs and NetWeaver-based flow diagrams require explicit definition of the conditions salmonids need for the completion of their lifecycle. This formalized and quantified model is now repeatable systematically throughout the assessments of all watersheds. Equally important, the explicit nature of the networks assists open communication to the general public through simple graphics and easily understood flow diagrams.

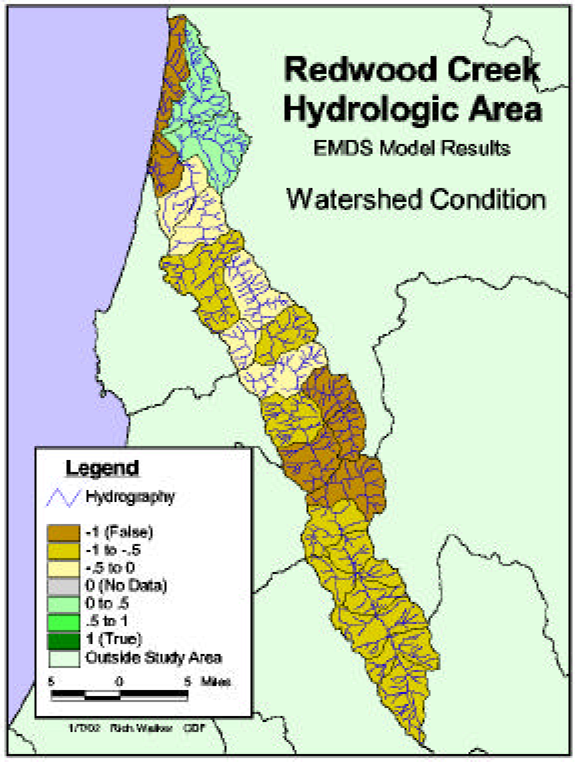

Figure 5: EMDS Graphical Output.

This example illustrates the graphical outputs of an EMDS run. Using incomplete and preliminary data, this demonstration graphic portrays the overall watershed condition ratings for the planning watersheds in Redwood Creek.

Another feature of the system is the ease of running alternative scenarios. Scientists and others can test the sensitivity of the assessments to different assumptions about the environmental factors and how they interact, through changing the knowledge-based network and breakpoints. “What-if” scenarios can be run by changing the shapes of reference curves (e.g., Figure 4), or by changing the way the data are combined and synthesized in the network.

NetWeaver/EMDS/ArcView tools can be applied to any scale of analysis, from reach specific to entire watersheds. The spatial scale can be set according to the spatial domain of the data selected for use and issue(s) of concern. Alternatively, through additional network development, smaller scale analyses (i.e., subwatersheds) can be aggregated into a large hydrologic unit. With sufficient sampling and data, analyses can even be done upon single or multiple stream reaches.

EMDS and NetWeaver are public domain software (NetWeaver on a trial basis), available to anyone at no cost over the Internet. Although NCWAP will employ EMDS and NetWeaver for watershed synthesis, this is not meant to preclude the use of other

Table 1: Reference Curve Metrics for EMDS Watershed Condition Model.

Watershed Condition Factor	Reference Curve Metric
Roads	
Road Use	Undefined; no data available
Road Crossings	No. of road crossings/km of streams <25th percentile fully suitable; >75th percentile fully unsuitable
Road Density by Hillslope Position	<25th percentile fully suitable; >75th percentile fully unsuitable; weightings, as detailed below, were used to apply a higher weight to roads lower on the slope.
road length on lower slopes	Density of roads of all types on lower 40% of slopes; weighted 0.6
road length on lower slopes	Density of roads of all types on mid-slope (41-80 % of slope distance); weighted 0.3
road length on upper slopes	Density of roads of all types on upper 20% of slopes; weighted 0.1
Road Density on Unstable Slopes	Length of roads on unstable slopes; <25th percentile fully suitable; >75th percentile fully unsuitable
Road Proximity to Streams	Length of all roads within 200' of stream ÷ length of all streams
Stream Condition	
Reach Condition	Input from EMDS Reach Condition Model
Stream Flow	This portion of model currently not used do to lack of data; see appendix for more details
Riparian Conditions	
canopy	Percent area of riparian vegetation within 200' feet of stream and compared to canopy closure on reference streams.
large woody debris potential	Percentage of stream bordered by mature forest stands with quadratic mean diameter of >=24 inches as compared to reference streams.
Fish Passage Barriers	Percentage of historically accessible streams currently accessible to anadromous fish; <50% fully unsuitable; 100% fully suitable
Upland Condition	
Upland Cover	
canopy	Percent area of forest communities with canopy structure within pre-European range of variation; <30% fully unsuitable; >75 % fully suitable
early seral	Percent area in early seral conditions due to stand-replacing natural or human disturbance within past 10 years; <10% fully suitable; >30% fully unsuitable
Land Use	
land use on **stable** slopes	Slope stability defined with SHALSTAB shallow slope stability model; DMG landslide hazard maps will be used when completed
• intensive land use on stable slopes	
--developed areas	Percentage of the watershed area in high density buildings and pavement
--farmed areas	Percentage of watershed area in intensive crop cultivation
• timber harvest on stable slopes	Percentage of watershed area tractor logged weighted by time period; see EMDS appendix for details
• ranch area on stable slopes	Percentage of watershed area used for grazing livestock; estimated based on vegetation type and parcel type
land use on **unstable** slopes	Slope stability defined with SHALSTAB shallow slope stability model; DMG landslide hazard maps will be used when completed
• intensive land use on unstable slopes	
--developed area	Percentage of the watershed area in high density buildings and pavement
--farmed area	Percentage of watershed area in intensive crop cultivation
• timber harvest on unstable slopes	Percentage of watershed area tractor logged weighted by time period; see appendix for details
• ranch area on unstable slopes	Percentage of watershed area used for grazing livestock; estimated based on vegetation type and parcel type
Slope Stability	Slope stability defined with SHALSTAB shallow slope stability model; DMG landslide hazard maps will be used when completed; <25th percentile fully suitable; >75th percentile fully unsuitable.

Table 2: Reference Curve Metrics for EMDS Stream Reach Condition Model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Water Temperature	
Summer MWAT	Maximum 7-day average summer water temperature <45^{o} F fully unsuitable, 50-60^{o} F fully suitable, >68^{o} F fully unsuitable. Water temperature was not included in current EMDS evaluation.
Riparian Function	
Canopy Density	Average percent of the thalweg within a stream reach influenced by tree canopy. <50% fully unsuitable, =85% fully suitable.
Seral Stage	Under development
Vegetation Type	Under development
Stream Flow	Under development
In-Channel Conditions	
Pool Depth	Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively. =20% fully unsuitable, 30 – 55% fully suitable, =90% fully unsuitable
Pool Shelter Complexity	Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation. =30 fully unsuitable, =100 - 300 fully suitable
Pool frequency	Under development
Substrate Embeddedness	Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments. EMDS calculates categorical embeddedness data to produce evaluation scores between –1 and 1. The proposition is fully true if evaluation sores are 0.8 or greater and -0.8 evaluate to fully false
Percent fines in substrate <0.85mm (dry weight)	Percent of fine sized particles <0.85 mm collected from McNeil type samples. <10% fully suitable, > 15% fully unsuitable. There was not enough of percent fines data to use Percent fines in EMDS evaluations
Percent fines in substrate < 6.4 mm	Percent of fine sized particles <6.4 mm collected from McNeil type samples. <15% fully suitable, >30% fully unsuitable. There was not enough of percent fines data to use Percent fines in EMDS evaluations
Large Woody debris	The reference values for frequency and volume is derived from Bilby and Ward (1989) and is dependant on channel size. See appendix for details Most watersheds do not have sufficient lwd surveys for use in EMDS.
Refugia Habitat	Refugia is composed of backwater pools and side channel habitats and deep pools (>4 feet deep). Not implemented at this time.
Pool to Riffle Ratio	Under development
Width to Depth Ratio	Under development

knowledge base expert systems, approaches, or models for further exploration of fish-environment relationships.

Management Applications of Watershed Synthesis Results

While EMDS-based syntheses are important tools for watershed assessment, they do not by themselves yield a course of action for restoration and land management. EMDS results require interpretation, and how they are employed depends upon other important issues, such as social and economic concerns. In addition to the accuracy of the expert opinion and knowledge base system constructed, the currency and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. Where possible, external validation of the EMDS model using fish population data and other information should be done.

EMDS syntheses can be used at the basin scale, to show current watershed status. Maps depicting those factors that may be the largest impediments, as well as those areas where conditions are very good, can help guide protection and restoration strategies. The EMDS model also can help to assess the cost-effectiveness of different restoration strategies. By running sensitivity analyses on the effects of changing different habitat conditions, it can help decision makers determine how much effort is needed to significantly improve a given factor in a watershed and whether the investment is cost-effective.

At the project planning level, the model results can help landowners, watershed groups and others select the appropriate types of restoration projects and places (i.e., planning watersheds or larger) that can best contribute to recovery. Agencies will also use the information when reviewing projects on a watershed basis.

The main strength of using NetWeaver/EMDS/ArcView knowledge base software in performing limiting factors analysis is its flexibility, and that through explicit logic, easily communicated graphics, and repeatable results, it can provide insights as to the relative importance of the constraints limiting salmonids in North Coast watersheds. NCWAP will use these analyses not only to assess conditions for fish in the watersheds and to help prioritize restoration efforts, but also to facilitate an improved understanding of the complex relationships among environmental factors, human activities, and overall habitat quality for native salmon and trout.

Limitations of the EMDS Model and Data Inputs

We want to stress that EMDS is an indicative model. That is, it indicates what the quality of watershed or instream conditions are, based on available data and the model structure. It is not intended to provide highly definitive answers, such as a statistically-based process model might. It does provide a reasonable first approximation of conditions through a robust information synthesis approach; however its outputs need to be considered and interpreted in the light of other information sources and the inherent limitations of the model and its data inputs. It also should be clearly noted that EMDS does not assess the marine phase of the salmonid lifecycle, nor does it consider fishing pressures.

The version of the EMDS model used in this report is preliminary (version 1.1) and evolving. It was developed based on the EMDS model developed for use in coastal Oregon, with modifications made on the basis of additional scientific information, standards established in the DFG restoration manual, discussion among NCWAP staff, and an EMDS workshop which included participants from the NCWAP team, other state and federal agency staff, and scientists. The University of California conducted this workshop. As noted above, NCWAP and UC are currently developing a follow-up team of scientists and practitioners to review help improve the current version of the model. It is anticipated that this process will be completed in time to allow the model improvements to be incorporated into the final draft of this report, which we expect to release in May 2002.

NCWAP staff has identified a number of model or data elements needing attention and improvement in the next version. These include:

- integration of stream temperature information into the model;
- development of fish passage barrier information for inclusion in the model;
- development of stream flow information for inclusion in the model;
- examination of the "operators" that combine the various branches of the model (e.g., "and" operators that pass forward the lowest value at a node versus "+" operators that pass the average value)
- use of residual versus maximum pool depth in the stream reach portion of the model;
- modification of canopy density standards for wide streams;
- incorporation of updated and improved vegetation data that will be available in February 2002;
- completion of quality control evaluation of several data layers;
- adjusting the model to better reflect differences between stream mainstems and tributaries;
- substituting DMG slope stability information (when completed) for slope stability estimates determined with the SHALSTAB shallow slope stability model.

The NCWAP team will address these limitations, to the extent possible, before the final draft of the Redwood Creek assessment report is completed in May 2002.

References

Reeves, G. 2001. Assessment of Ecosystem condition. Presentation given before California Resources Agency, Sacramento, Feb 9 2001.

Reynolds, K. 1999. EMDS users guide (version 2.0): knowledge-based decision support for ecological assessment. Gen. Tech. Rep. PNW-GTR-470. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p. http://www.fsl.orst.edu/emds/download/gtr470.pdf

Saunders, M.C. and B.J. Miller. No date. A GRAPHICAL TOOL FOR KNOWLEDGE ENGINEERS DESIGNING NATURAL RESOURCE MANAGEMENT SOFTWARE: NETWEAVER, http://mona.psu.edu/NetWeaver/papers/nw2.htm

II. NCWAP's EMDS Stream Reach Condition Model

Introduction

The stream reach knowledge base uses all available data for a stream reach to test the proposition: Conditions in the stream reach are suitable to sustain healthy populations of anadromous salmonids.

The stream reach knowledge base is composed of four logic networks relating to environmental factors that affect anadromous salmonid habitat conditions: 1) Water Temperature; 2) Riparian Vegetation Function; 3) Stream Flow; and 4) In Channel Conditions (Figure 3). The overall Stream Reach Condition is determined by combining the four evaluations through the "AND" logic node. This evaluates to 'true' (+1) when all the network evaluations are 'true', 'false' (-1) if any of the four network evaluations is 'false', or a numerical value between +1 and –1, showing the degree to which the above proposition is 'true'.

A summary of the Stream Reach Condition knowledge base used in the EMDS model is presented below. For each parameter in the model, its proposition, definition and explanation are presented.

Water Temperature

Proposition:

Summer water temperature is suitable sustain healthy populations of anadromous salmonids.

Definition:

Water temperature at the reach level is evaluated by one of three metrics:

1) Yearly 24 hour maximum temperature
2) Maximum 7-day average temperature
3) Maximum 7-day maximum temperature

Explanation:

The maximum 7-day average temperature measured from continuous temperature recorders are compared to reference values derived from experimentally and empirically determined MWAT's for anadromous salmonids. A review of the literature shows numerous studies stressing the importance of stream temperature for fish (see list of references below). Reference values for this parameter we selected from a synthesis of relevant studies.

Data Sources:

Temperature monitoring devices (such as hobo temps) which provide a sample of stream temperatures.

Reference Values:

The proposition for water temperature is fully true if the maximum 7-day average summer temperature from field observations is between 50 and 60 degrees fahrenheit (F) and fully false if the maximum 7-day average summer temperature is below 45 degrees F or above 68 degrees F. The reference value curve for the maximum 7-day average temperature is shown below (figure 4).

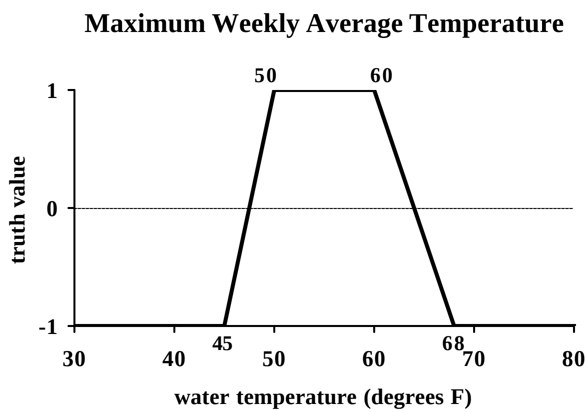

Figure 4. Breakpoints for MWAT truth values

Riparian Vegetation Function

Proposition:

Current riparian vegetation provides sufficient shade, nutrients, large woody debris recruitment, and contributes to bank stability to maintain healthy populations of anadromous salmonids.

Definition:

The riparian vegetation assessment consists of an evaluation of canopy density which shades the stream channel and an evaluation of the near-stream forest's ability to provide LWD and nutrients to the stream channel. (Seral stage and species composition is still under construction).

The Riparian Vegetation Function network is composed of an evaluation of:

1) Canopy Density

and the mean value of the evaluation of:

2) Canopy Species Composition
3) Live Mature Trees
4) Imminent Source of Large Woody Debris.

Canopy Density

Proposition:

Canopy density is provides adequate shade to help maintain suitable water temperature and nutrient input to maintain healthy anadromous salmonid populations.

Definition:

Canopy density is the percent of stream influenced by tree canopy measured with a spherical densiometer from the center of a stream habitat unit.

Explanation:

Shade from streamside canopy helps to reduce stream water temperatures, especially during summer months. This parameter measures the adequacy of the vegetation in performing this important role.

The California Department of Fish and Game's Salmonid Stream Habitat Restoration Manual recommends, in general, that revegetation projects should be considered when canopy density is less than 80% (Flossi et al. 1998). Naiman et al. (1992) report that in westside forests the amount of solar radiation reaching the stream channel is approximately 1 - 3% of the total incoming radiation for small streams and 10 -25% for mid-order (3^{rd} to 4rth order) streams.

Data Sources:

Field measurements in the stream reaches.

Reference Values:

The proposition for Canopy Density is fully true if field observations are 85 percent or above and fully false if field observations are below 50 percent (see figure 5).

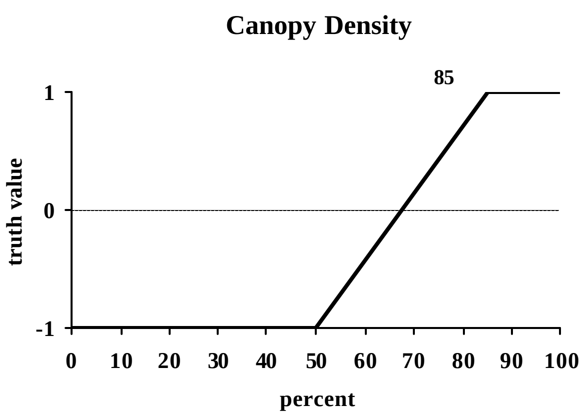

Figure 5. Breakpoints for Canopy Density

Canopy Species Composition

Proposition:

The canopy species composition is within the range of historic species distribution and is suitable to maintain healthy anadromous salmonid populations. (Not yet implemented in the model, due to lack of adequate data).

Definition:

The similarity of species and lifeforms between the current vegetation and that which exited prior to EuroAmerican colonization.

Explanation:

The species composition of the riparian vegetation can indicate recent historical events that have occurred in and near the stream reach. Some areas currently dominated by broad-leafed trees were dominated in the past by conifers. This can indicate that disturbances have occurred in the watershed which resulted in this change in species composition. Also, conifers tend to provide more cooling in their shade than broad-leaf trees.

Data Sources:

Measurements from field observations.

Reference Values:

The proposition is fully true if the observed canopy species composition has a high degree of similarity to the pre-EuroAmerican range of species composition and fully false if it has a low similarity.

Live Mature Trees (not yet implemented)

Proposition:

The number of live trees three feet or greater in diameter at breast height within a riparian buffer zone is sufficient to maintain conditions needed to support healthy anadromous salmonid populations. (The reference value curves and other aspects have not yet been developed for Live Mature Trees.)

Imminent Source of Large Woody Debris (LWD) (not yet implemented)

Proposition:

The number of LWD sources poised for imminent delivery to the stream channel is suitable to maintain channel conditions suitable to support anadromous salmonid populations. (The reference value curves and other aspects have not yet been developed for this parameter.)

Stream Flow (not yet implemented)

Proposition:

The stream flow regime is suitable to sustain healthy populations of anadromous salmonids. (This subnetwork of the Stream Reach model is under construction by the Department of Water Resources. It is not yet ready for inclusion in the Stream Reach Condition Model.)

In-channel Conditions

Proposition:

In-channel conditions are suitable to support healthy anadromous salmonid populations

Definition:

In-channel conditions are determined by the mean truth value returned by the evaluation of 5 networks:

1) Large Woody Debris
2) Width to Depth Ratio
3) Pool Habitat
4) Refugia Habitat
5) Substrate Composition.

Large Woody Debris

Proposition:

The amount of in channel Large Woody Debris is suitable for maintaining channel conditions to support healthy populations of anadromous salmonids.

Definition:

The target reference values for LWD frequency and volume is derived from Bilby and Ward's (1989) channel-width dependent regression for unmanaged streams in western Washington. The relationships between channel width and number of pieces (Bilby and Ward 1989) and "key" pieces of LWD (Fox 1994) is presented in the Pacific Lumber company Habitat Conservation Plan, Aquatic Properly Functioning Condition Matrix (work in progress 1997). NMFS also has provisional data for wood in Washington Coast Range Streams. They concluded that where adequate sources for recruitment of wood is present from the riparian zone, properly functioning streams exceed 80 pieces per mile of wood larger than 24 inches in diameter and 50 feet in length.

Explanation:

Large woody debris is important to stream ecosystems because it exerts considerable control over channel morphology, particularly in the development of pools (Keller et al.). Petersen and Quin (1992), cited Elliot, 1986; Murphy et al. 1986; Carson et al. 1990; Beechie and Wyman, 1992, when noting that "in forested streams, LWD is associated with the majority of pools and the amount of LWD has a direct affect on pool volume, pool depth and percentage of pool area in a stream." Stillwater Sciences' Preliminary Draft Report suggests: "One of the working hypotheses concerning coho salmon ecology and management in Mendocino county streams is that large woody debris (LWD), and the rearing habitat that it provides, may currently be the most important factor limiting coho populations." The North Coast Water Quality Control Board in cooperation with the California Department of Forestry (1993) state that,"woody debris benefits all life stages of salmonids (Bisson et al. 1987, Sullivan et al 1987) by creating pools which are used as holding areas during migration. Large woody debris also serves to retain spawning gravels, creates slack water areas which provide opportunities for juveniles to feed on drift, and by providing essential cover from predators and freshets (Murphy and Meehan 1991). Woody debris in stream also increases the frequency and diversity of pool types (Bilby and Ward, 1991)."

The majority of juvenile coho in coastal streams appear to overwinter in deep pools within the stream channel that have substantial amounts of cover in the form of woody debris (Bustard and Narver 1975a, Scarlett and Cederholm, 1984, Murphy et al 1986, Brown and Hartman, 1988).

Swimming ability decreases with temperature and as water temperature falls below 9 C, juvenile coho become less active (Mason, 1966). Feeding is reduced and growth is negligible during the winter period of higher flow and lower temperatures (Shapovalov and Taft, 1954)."

"Deep (>45 cm), slow (<15cm/s areas in or near (<1m) instream cover or roots, logs, and flooded brush appear to constitute preferred habitat (Hartman, 1965, Bustard and Narver, 1975a), especially during freshets (Tschaplinski and Hartman, 1983; Swales et al 1986, McMahon and Hartman, 1989). Underwater observations by Shirvell (1990) found that 99% of all coho salmon fry observed were occupying positions downstream of natural or artificial rootwads, during artificially created drought, normal, and flood stream flows."

<u>Data Sources</u>:

Measurements from field observations.

<u>Reference Values</u>:

(need help on this Steve)

Width-to-Depth Ratio (not yet implemented)

<u>Proposition:</u>

The Width-to-Depth Ratio of the stream reach is suitable for sustaining healthy populations of anadromous salmonids. (The reference valuse curves have not yet been developed for this parameter.)

Pool Habitat

Proposition:

The pool frequency, pool depth, and pool complexity observed in the stream reach is suitable to support healthy populations of anadromous salmonids.

Definition:

The Pool Habitat sub-network evaluation is composed from evaluations of:

1) Pool Frequency
2) Pool Quality:
    a) Pool Depth
    b) Pool Complexity

Pool Frequency

Proposition:

The number of pools observed during stream surveys is within the suitable frequency range for the channel type, gradient, bankfull width, and channel confinement of the stream reach.

Definition:

The number of pools observed per unit length of stream reach.

Explanation:

Reference Values:

The proposition is fully true if the observed pool frequency has a high degree of similarity to the expected frequency range and fully false if it has a low similarity. (need better definition)

Pool Quality

Proposition:

The percent by stream reach of adequately Deep Pools and the average Pool Shelter Complexity is suitable to support healthy populations anadromous salmonid populations.

Definition:

The percent reach of primary pools is calculated by: length of primary pool habitat / stream reach length.

Explanation:

The percent by stream reach of adequately deep pools or primary pools is determined according to stream order. Primary pools have a maximum depth of 2.5 feet or greater in first and second order streams and have a maximum depth of 3 feet or greater for third order streams. For this analysis, stream order is determined only from streams displayed as solid blue lines on 1:24,000 USGS topo maps.

A DFG field procedure rates pool habitat shelter complexity (Flosi et al. 1998). The pool shelter rating is a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation that serves as instream habitat, creates areas of diverse velocity, provides protection from predation, and separation of territorial units to reduce density related competition. The rating does not consider factors related to changes in discharge, such as water depth. The proposition for the Pool Shelter Complexity evaluation is fully true if the pool shelter rating is 100 or greater and fully false if the pool shelter rating is 30 or less (figure7).

Data Sources:

Notes from field observations.

Reference Values:

The proposition for the Pool Depth evaluation is fully true if 30 to 55 percent of the reach is in primary pools and fully false if there is less than 20 percent or more than 90 percent primary pool habitat (figure 6).

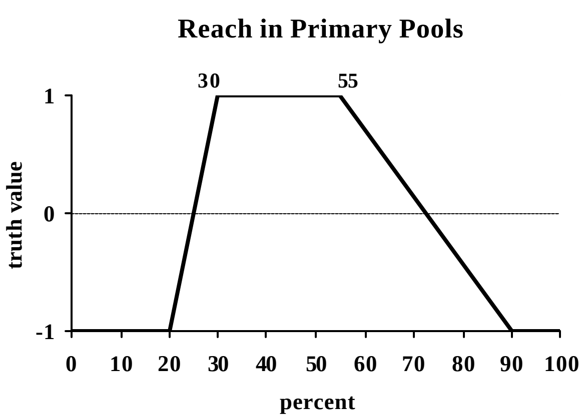

Figure 6. Breakpoints for Percent Reach in Primary Pools

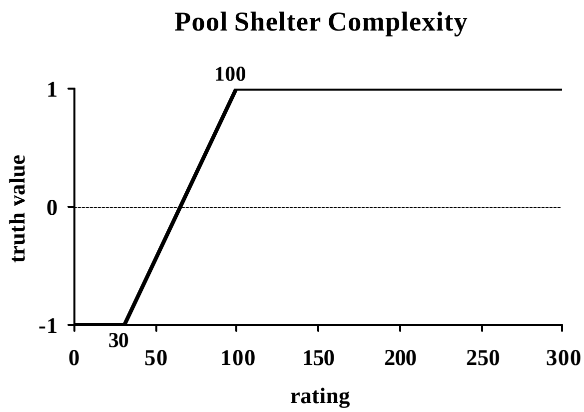

Figure 7. Breakpoints for Pool Shelter Complexity

Refugia Habitat

<u>Proposition:</u>

The amount of backwater pools, deep pools and side channel habitats is suitable (especially as winter refuge) to support healthy anadromous salmonid populations.

<u>Definition:</u>

Refugia for this evaluation is composed of backwater pools, side channel habitat, and deep pools (>4 feet deep) identified from DFG's stream habitat surveys.

<u>Explanation</u>:

For this evaluation, we believe that the amount of refugia should be approximately 5 percent of the stream reach measured by the length of backwater pools and side channel habitat. The reference values for the suitable amount of deep pool habitat is under development.

<u>Data Sources</u>:

Observations from the field.

<u>Reference Values</u>:

The proposition for the Refugia Habitat evaluation is fully true if there is 5 percent of the stream reach in side channel or backwater pools and fully false if there is no such habitat in the stream reach (figure 8).

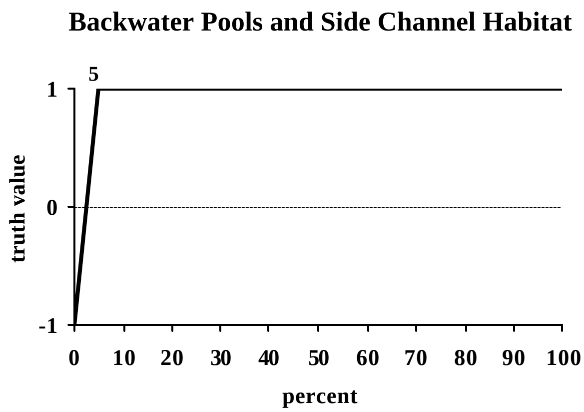

Figure 8. Breakpoints for Percentage in Backwater Pools and Side Channel Habitat

Substrate Composition

Proposition:

The pool tail and riffle substrate is suitable for survival of salmonid eggs to emergence of fry.

Definition:

The model will utilize data describing percent fine sediments collected from McNeil type samples, pool tail embeddedness from DFG habitat surveys, and pebble counts to evaluate substrate composition.

Percent Fine Sediment

Explanation:

Substrate composition is used as a suitability measure of pool tail sediments for survival of eggs to the emergence of fry. Sedimentation resulting from land use activities is recognized as a fundamental cause of salmonid habitat degradation (FEMAT, 1993). Excessive accumulations of fine sediments reduces water flow (permeability) through gravels in redds. The percent of fine sediments is higher in watersheds where the geology, soils, precipitation or topography create conditions favorable for erosional processes (Duncan and Ward, 1985). Fine sediments are typically more abundant where land use activities such as road building or land clearing expose soil to erosion and increase mass wasting (Cederholmn et al 1981; Swanson et al 1987; Hicks et al 1991).

McHenry et al. (1994) Found that when fine sediments (<0.85mm) exceeded 13% (dry weight)salmonid survival dropped drastically. Bjornn and Reiser (1991) show that the salmonid embryo survival drops considerably when the percentage of substrate particles smaller than 6.35 mm exceeds 30 percent.

Data Sources:

Field measurements.

Reference Values:

Reference values curves for Percent Fine Sediment are presented figures 9 and 10 (below).

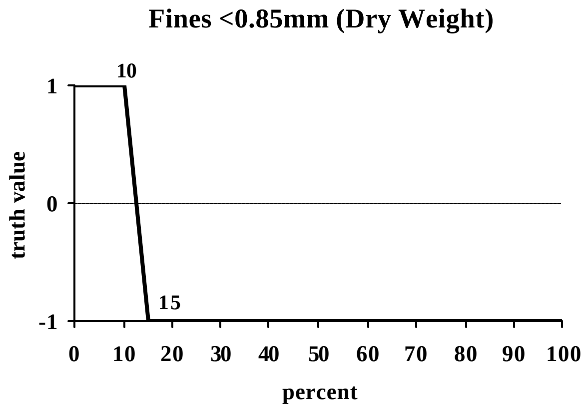

Figure 9. Breakpoints for Percent Dry Weight of Fine Sediments <0.85mm

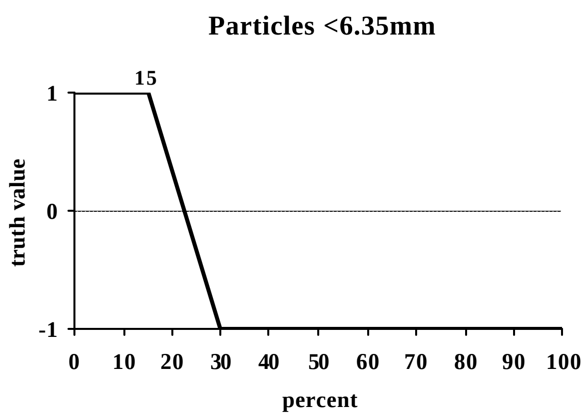

Figure 10. Breakpoints for Percent of Sediments <6.35mm

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III. NCWAP's EMDS Watershed Condition Model

Introduction

NCWAP scientists, agency personnel and others constructed a Watershed Condition knowledge base network reflecting the interrelationships of environmental factors which affect populations of salmonid on California's north coast. The model integrates those factors which operate over a whole small watershed. In this section we summarize the NCWAP EMDS knowledge base components and how they are combined into the synthesis of watershed condition.

Watershed Condition is evaluated from four equally-weighted branches: 1) Roads; 2) Stream Condition; 3) Passage Barriers; and 4) Upland Condition (figure 11). The final 'AND' decision node of Watershed Condition is evaluated to be effectively the *worst condition* as determined by the four branches.

In the Watershed Condition model, all but two parameters use empirical distributions for the break points in the evaluations. The literature is rich in many aspects regarding the effects of roads, riparian condition, stream flows and land use on water quality and salmonid habitat (see references). However, very few studies provide direct guidance on where to set breakpoints for the parameters required in the Watershed EMDS model. In light of this fact, NCWAP scientists decided that while an absolute objective evaluation may not be possible (or at least scientifically defensible) for all watersheds, evaluation of relative conditions within a watershed would be much more robust. For each hydrologic area (e.g. the Mattole River) breakpoints are determined based upon the normalized distance from the mean (i.e. percentiles) from the statistics of the distribution of given parameter. Within this framework it is still possible to look beyond a hydrologic area to larger regions by aggregating the statistics. Extrapolating in this manner may be more tenuous than looking more locally, due to the likelihood of changes in data quality and availability from one area to another.

Below is a summary of the workings of the NCWAP Watershed Condition model.

Roads

<u>Proposition:</u>

Roads in the watershed do not significantly impair water quality in the watershed through increased fine sediment and alteration of the hydrologic regime, and are compatible with healthy populations of native salmonids.

<u>Definition:</u>

The overall roads condition represents the mean truth value returned from five sub networks: 1) road use, 2) road and stream crossings, 3) road density, 4) road density on unstable slopes, 5) road proximity to streams. Figure 3 shows the diagram on the roads part of the watershed condition model.

Explanation:

Road Condition represents the potential impact of roads on a watershed's water quality, and, by extension, on native fish. Five metrics, listed above, are used to represent the intensity of road use and the degree to which roads are hydrologically connected to streams. The metrics are derived using digital road and stream data. These metrics are influenced by the level of detail provided in the roads database. The minimum coverage for a basin corresponds with roads found on 1:24,000 scale USGS topographic maps. In most cases, these databases are augmented with roads interpreted from air photos and those recorded in timber harvest plans. Planning watersheds that have truth values that are at or near positive one, strongly support the proposition that roads do not represent an impairment.

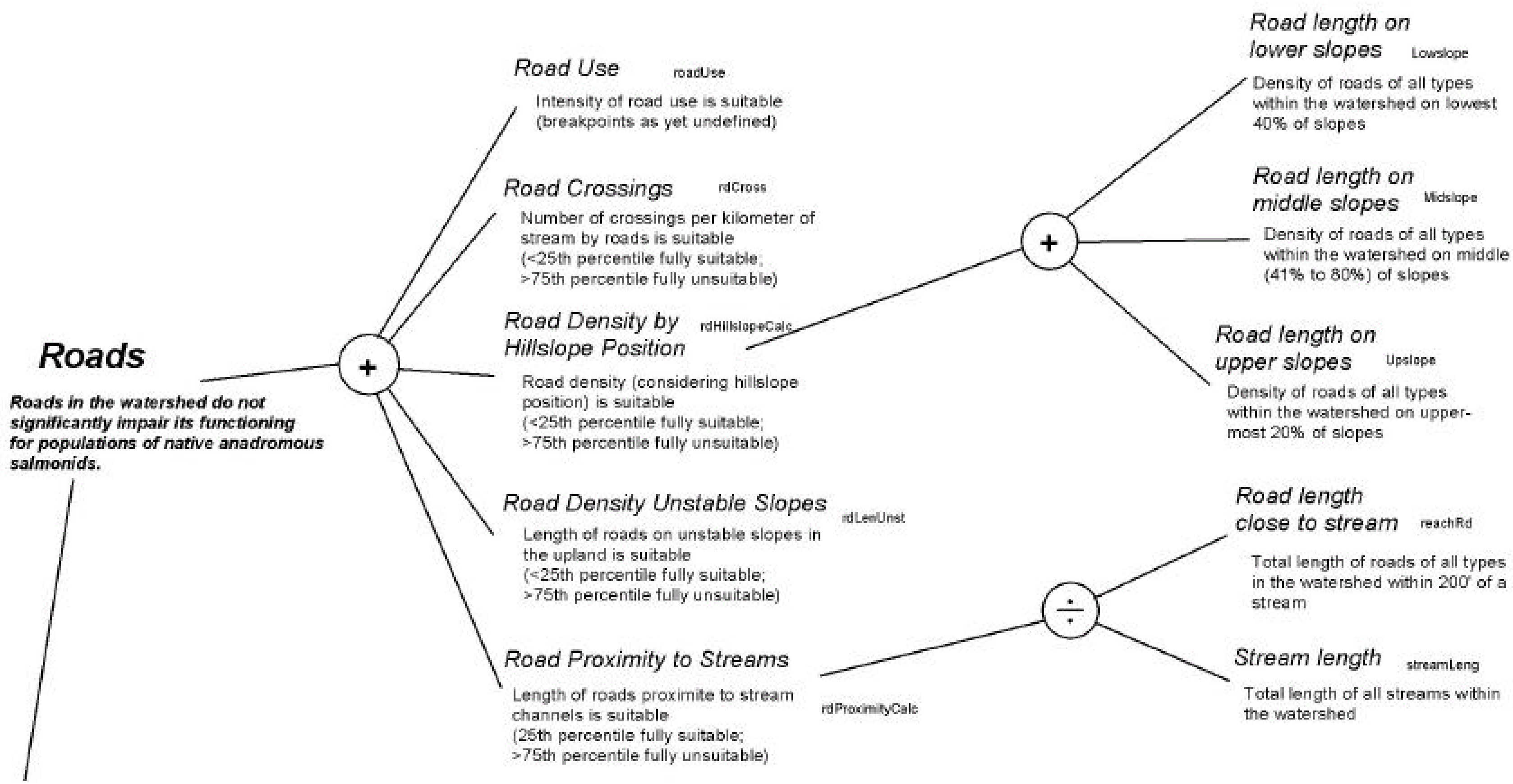

Figure 12. The EMDS knowledge base section that takes data related to roads, and combines them into their net effects on a watershed.

Road Use

Proposition:

Intensity of road use is suitable for sustaining healthy populations of native salmonids. (This parameter is not currently implemented for lack of adequate data)

Definition:

Road Use is evaluated for planning watersheds using four catagories: low, medium, high and very high. Determination of these classes is currently based on professional judgement.

Explanation:

This metric is designed to represent the impacts associated with the volume of road use in a watershed. The network is evaluated as a categorical variable (i.e. low, medium and high).

Data Source:

Information for this network typically relies on existing studies or previous watershed plans (i.e. TMDL reports).

Reference Values:

Break points planned for future (with data available): Low usage is fully suitable (+1) while very high is fully unsuitable (-1).

Road Crossings of Streams

Proposition:

The number of crossings (per kilometer) of stream by roads in the watershed does not significantly impair its suitability for sustaining healthy populations of anadromous salmonids.

Definition:

Evaluated as the number of stream crossings by roads per kilometer of stream.

Explanation:

Road networks interact with stream networks and have the potential to negatively impact stream condition. Impacts associated with this include: increased sediment, alteration of runoff processes, removal of canopy cover and blocking fish passage. This metric evaluates potential impacts. Road improvements and information on culverts can be incorporated into the model through a "Switch" node, which would reduce from the set of potential impacts those crossings that have been repaired and are no longer considered to have an impact.

Data Sources:

Road crossings per kilometer of stream in a given hydrologic area (HA) are derived in GIS from existing roads and streams coverages.

Reference Values:

Break points defining the road crossings of streams are based on distributions of empirical data. Values in a given hydrologic unit are normalized, and breakpoints are empirically defined as: <25^{th} percentile fully suitable; >75^{th} percentile fully unsuitable.

Road Density by Hillslope Position

Proposition:

Road density in the watershed is compatible with maintaining healthy populations of native salmonids. The criteria for acceptable varies with hillslope position.

Definition:

Road density by hillslope position for each planning watershed. Measurement units are mi/mi^2.

Explanation:

Each planning watershed is divided into three hillslope positions: low slope (valley bottom), mid slope and upper slope (ridge top). Previous studies have shown that road impacts differ, all other factors being equal, depending on the location of the road in the watershed. A recent USFS study on Bluff Creek watershed, Six Rivers National Forest, found that roads near streams, in lower hillslope positions, had a much higher failure rate, and thus a greater potential to generate sediment to streams. Based on the Bluff Creek study, slope position was defined as the following: low slope occupies the lowest 40% of the watershed, mid-slope occupies the middle 40% and ridge-top is defined as the upper 20% of the watershed.

Data Source:

Slope Position is derived from a 10 meter digital elevation model (DEM). Road Data comes from a variety of sources including: USGS 1:24,000 scale map digital line graph (DLG) data, 1 meter Digital Ortho Quads and digitized timber harvest plans.

Reference Values:

Break points defining road density curves are based on empirical data from each watershed. Values in a given hydrologic unit are normalized, and breakpoints are empirically defined as: <25^{th} percentile fully suitable; >75^{th} percentile fully unsuitable.

Road Density on Unstable Slopes

Proposition:

The density of roads on unstable slopes in the upland portion of the watershed is compatible with sustaining healthy populations of native salmonids.

Definition:

Calculates kilometers of road on unstable upland per hectare of management unit.

Explanation:

Roads crossing steep and potentially unstable slopes can contribute to and accelerate the frequency of mass wasting on upland slopes. Where data exists, detailed landslides maps (developed by Division of Mines and Geology) are overlain with roads within a GIS to evaluate the risk roads on steep and unstable slopes. Shalstab is used as a proxy in basins where detailed landslides maps are unavailable.

Data Source (all GIS-based):

Roads data; Landslide maps; Shalstab (potentially unstable is defined as Q/T <= log -2.8)

Reference Values:

Break points defining the road density on unstable slopes are based on distributions of empirical data. Road density values in a given hydrologic unit are normalized, and breakpoints are empirically defined as: <25th percentile fully suitable; >75th percentile fully unsuitable.

Road Proximity to Streams

Proposition:

The proximity of roads to stream channels that is suitable for maintaining healthy populations of native salmonids.

Definition:

Calculates the percent of stream length that has a road within 200 ft.. For each planning watershed it is evaluated as the sum of all reach lengths that have a road within a buffer distance of 200 ft.

Explanation:

This metric is a measure of hydrologic connectivity. Roads that are adjacent to streams are much more likely to interact with the stream channel and have a greater potential to negatively impact stream condition. The main impacts associated with this are increased sediment delivery to the streams, but studies have attributed impacts to stream temperature and alteration of runoff processes as well. Effects would also extend into the adjacent riparian zone. This metric evaluates potential impacts. Road improvements and road abandonement can be incorporated into the model through a

"Switch" node, which would reduce from the set of potential impacts those road segments that have been repaired or decommissioned and are no longer considered to have an impact.

Data Source (all GIS-based):

Roads data; Stream data

Reference Values:

Break points defining the road proximity to streams evaluations are based on distributions of empirical data. Values in a given hydrologic unit are normalized, and breakpoints are empirically defined as: <25^{th} percentile fully suitable; >75^{th} percentile fully unsuitable.

Stream Condition

Proposition:

Riparian and in-stream conditions in the watershed are suitable for sustaining healthy populations of anadromous salmonids.

Definition:

Stream Condition is effectively the *worst condition* evaluated from three branches or dependency networks: 1) Reach Condition (from the Stream Reach Condition EMDS model); 2) Stream Flow; and 3) Riparian Condition. (Water Temperature will be added in the next version of the model). Figure 13 shows the diagram on the stream condition part of the watershed condition model.

Explanation:

The stream condition network evaluates stream conditions across entire planning watersheds. The results of the stream reach model are integrated at this stage of the model. Overall reach condition represents the average of all truth values for the reaches within an individual planning watershed.

Reach Condition

Proposition:

Average reach conditions of anadromous fish bearing streams in the watershed are suitable to sustain healthy populations of anadromous salmonids. The Reach Model developed by the Department of Fish and Game provides input here (see above).

Stream Flow (not yet implemented)

Proposition:

Stream Flow in the watershed is similar to pre-EuroAmerican conditions and is suitable for sustaining healthy populations of anadromous salmonids.

Definition:

Stream Flow is the *mean condition* of a.) Total yield; b.) Peak flow; c.) Base flow; and d.) Bankfull discharge. For all of these, breakpoint values will of necessity vary by watershed. (Note: We have not activated this network in the current model runs, due to lack of data.)

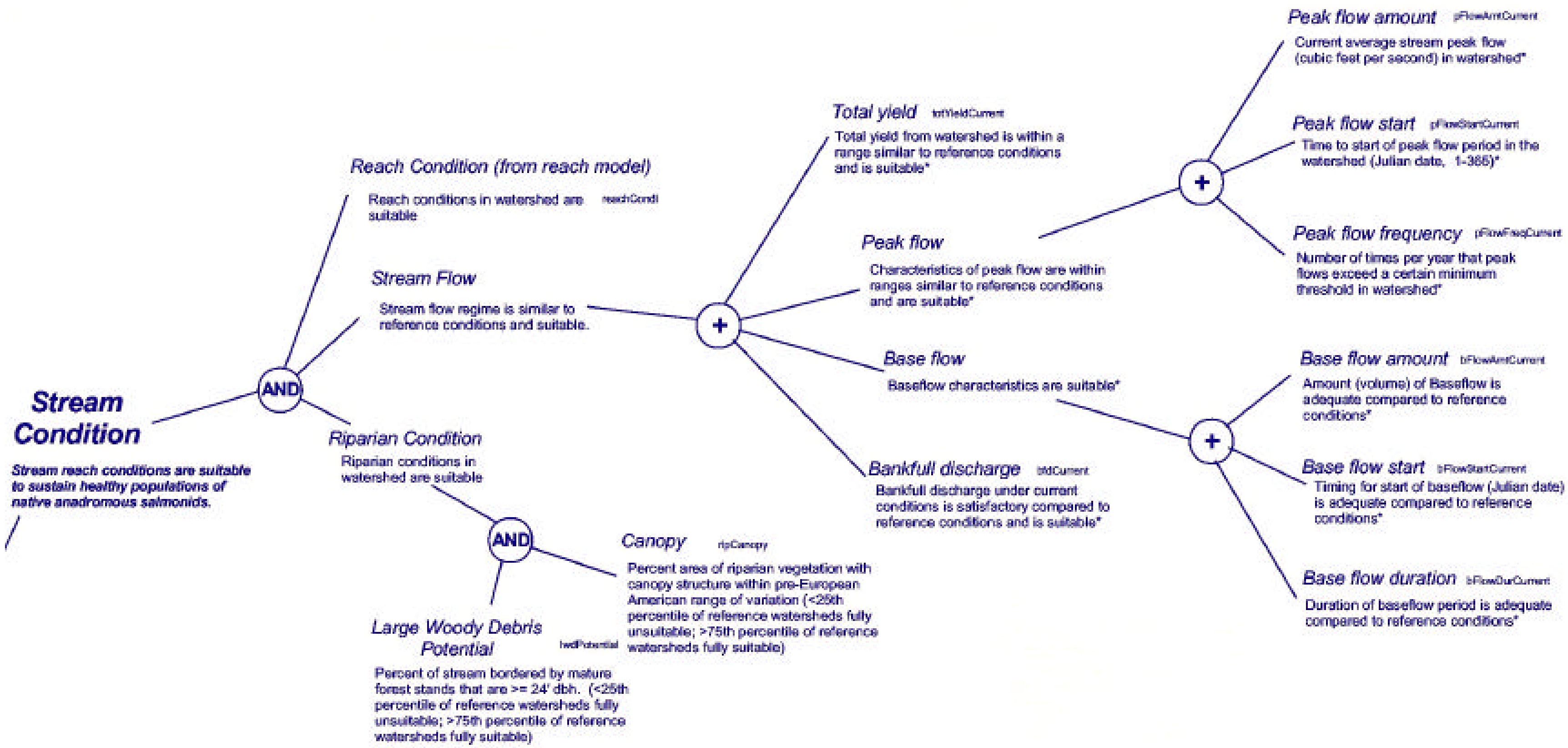

Figure 13. The EMDS knowledge base section that takes data related to stream condition, and combines them into an overall assessment of the watershed.

Total Yield (not yet implemented)

Proposition:
The mean annual total stream discharge is suitable for sustaining healthy populations of anadromous salmonids.

Peak Flow (not yet implemented)

Proposition:
The amount, start, and frequency of the peak flow is suitable for sustaining healthy populations of anadromous salmonids.

Base Flow (not yet implemented)

Proposition:
The amount, start and duration of the base flow is suitable for sustaining healthy populations of anadromous salmonids.

Bankfull Discharge (not yet implemented)

Proposition:
The bankfull discharge is suitable for sustaining healthy populations of anadromous salmonids.

Riparian Condition

Proposition:
Riparian condition is suitable for sustaining healthy populations of native salmonids.

Definition:
Riparian Condition is evaluated as effectively the *worse condition* of 1) Riparian Canopy and 2) Large Woody Debris Potential.

Riparian Canopy

Proposition:
The riparian canopy in the watershed is suitable for sustaining healthy populations of anadromous salmonids.

Definition: planning watershed, bordered by mature forest stands that have an average dbh exceeding 24".

Explanation:

Riparian forests provide shade for streams and contribute wood to streams that in turn provide habitat for fish. On the North Coast both canopy and large woody debris can be limiting factors for salmon. Canopy cover is derived from sattelite images and air photos. The data is much coarser that field observations, provided at the reach level, but provide estimates across the entire watershed.

Data Source (all GIS-based):

Stream data; USFS/CDF vegetation data

Reference Values:

Break points defining the riparian canopy curve are based on distributions of empirical data derived from reference watersheds. Reference watersheds are assumed to have little or no land disturbance. Breakpoints are then empirically defined as: $<25^{th}$ percentile is fully unsuitable; $>75^{th}$ is fully suitable.

Large Woody Debris Potential

Proposition:

The percentage of stream bordered by mature forest stands is suitable for sustaining healthy populations of anadromous salmonids.

Definition:

Mature forest stands are defined as >= 24” dbh.

Explanation:

Tree size represents a proxy for the recruitment of large woody debris.

Data Source (all GIS-based):

Stream data; USFS/CDF vegetation data

Reference Values:

Break points defining the riparian canopy curve are based on distributions of empirical data derived from reference watersheds. Reference watersheds are assumed to have little or no land disturbance. Breakpoints are then empirically defined as: $<25^{th}$ percentile is fully unsuitable; $>75^{th}$ is fully suitable.

Passage Barriers

Proposition:

Fish have adequate access in the watershed to those stream reaches which have sustained populations in the past.

Definition:

Passage Barriers is defined as the percentage of historically accessible stream length that is currently accessible to anadromous fish.

Reference Values:

Breakpoint values are: < 50% = fully unsuitable; 100% = fully suitable. This is based upon expert opinion from California Department of Fish and Game (See figure 14 below). (Note: Passage Barriers is not currently implemented in the model due to lack of data).

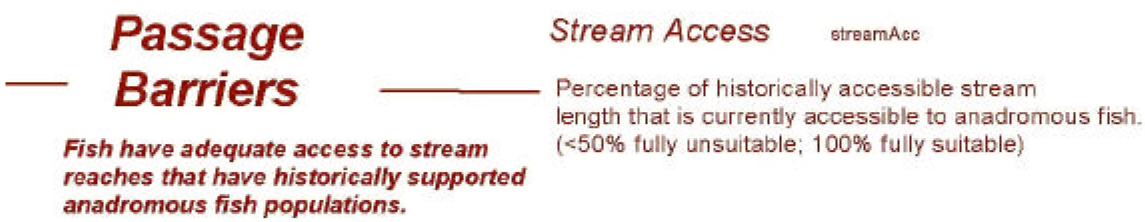

Figure 14. The section of the knowledge base that determines the relationship between past and present fish access to tributaries in the watershed.

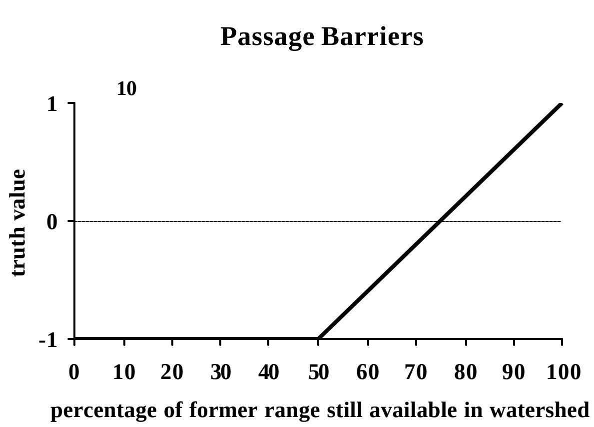

Figure 15. Breakpoints for passage barriers

Upland Condition

Proposition:

The upland conditions in the watershed are suitable to sustain healthy populations of native salmonids.

Definition:

Upland Condition is the *mean condition* of three branches (dependency networks): 1) Upland Cover; 2) Land Use; and 3) Slope Stability. Figure 6 shows the diagram on the upland condition part of the watershed condition model. Each is described in turn below.

Explanation:

Upland Condition is a measure of the state of the watershed uplands in relation to its suitability for salmonids. For a given planning watershed, the parameter takes into account the distribution of seral stages of the vegetation, the percentage area of recent stand-replacing disturbances, the degree to which it is apt to be affected by land use, and its inherent (background) slope stability.

Upland Cover

Proposition:

Both canopy structure and the total area of early seral vegetation are suitable for sustaining healthy populations of native salmonids.

Definition:

Upland Cover is effectively the *worse condition* of: a) Canopy and b) Seral Openings.

Canopy

Proposition:

The distribution of vegetation canopy structure in the uplands of the watershed is suitable for sustaining healthy populations of native salmonids.

Definition:

Canopy is percentage area of the watershed's vegetation that is within the natural (pre-EuroAmerican colonization) range of variability.

Explanation:

The Canopy parameter reflects the watershed's current distribution of vegetation seral stages (early through climax) in relation to probable pre-EuroAmerican conditions. The watershed natural range of variability is not a constant, but varies spatially across the north coast region, related to the climate and fire regimes. Vegetation in watersheds close to the coast is more likely to be shaped by infrequent large-scale (and frequent local-scale) events, whereas areas

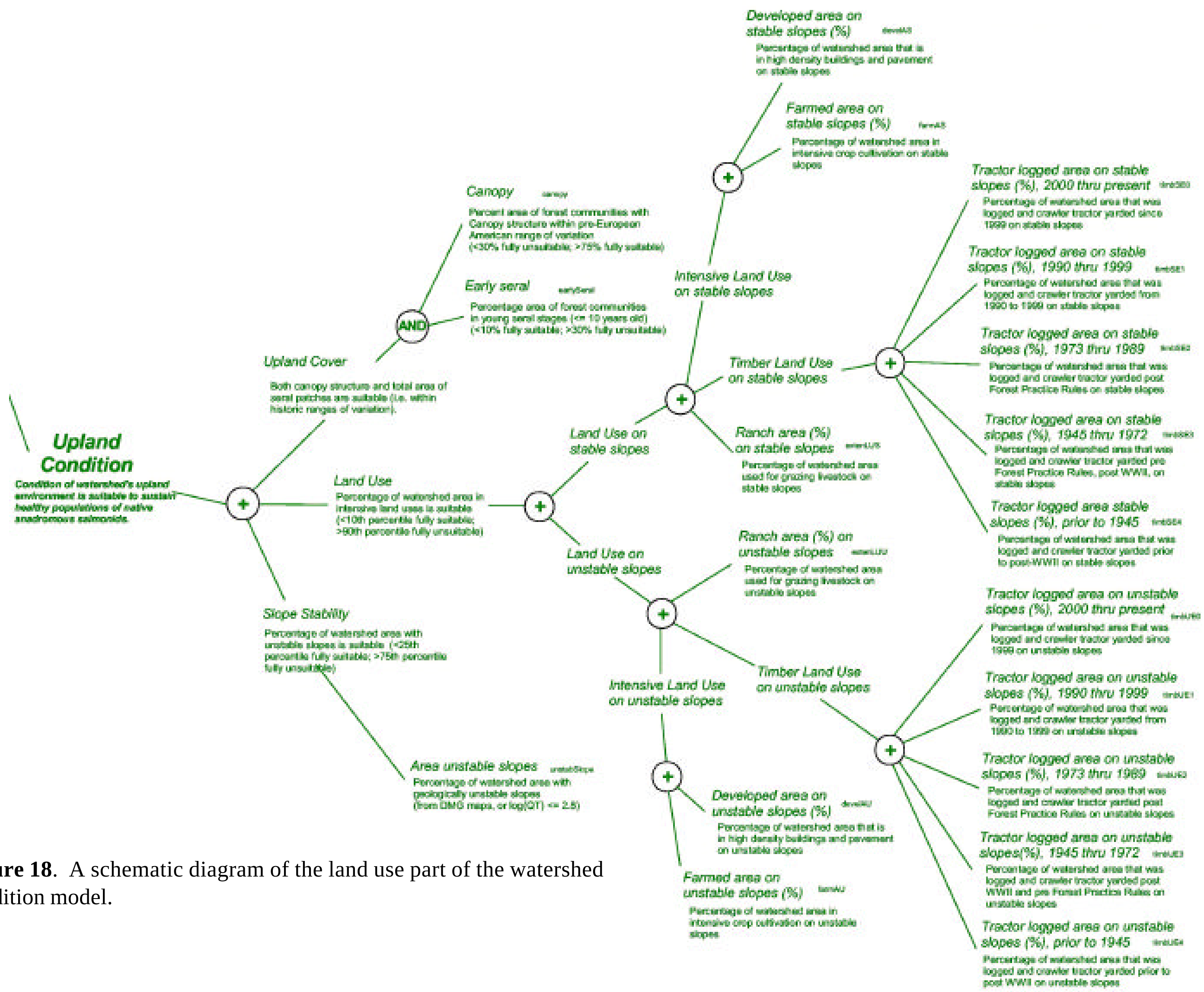

Figure 18. A schematic diagram of the land use part of the watershed condition model.

more to the interior have historically experienced more frequent larger-scale events (Sawyer et al. 2000).

Several computer based models have been developed to simulate the distribution of vegetation seral stages under various management and disturbance regimes. These include: Landscape Age-Class Dynamics Simulator (LADS) (Wimberly et al. 2000); Vegetation Dynamics Development Tool (VDDT) (e.g. Quigley et al. 1997); Simulating Processes and Patterns at Landscape Scales (SIMPPLLE) (Chew 1995); and Forest Vegetation Simulator (FVS) (Crookston and Stage 1999). Such models can be used to approximate distributions of vegetation seral stages across landscapes of various sizes. A consideration in this modeling effort is that high intensity disturbances such as fire often affect areas larger than a planning watershed (Wimberly, et al. 2000), and applying models of vegetation dynamics at this Calwater scale may be inappropriate.

NCWAP scientists have not run any vegetation simulation models at this point to approximate the Canopy parameter for EMDS. As a proxy we are currently using the total percentage of the watershed that contains forests with trees of DBH > 24”.

Data Source(s):

GIS coverage from Region 5 of the US Forest Service of current vegetation

Reference Values:

The curve breakpoints are taken from the EMDS model created by Reeves, Reynolds, et al. for the Coho salmon on the Oregon coast. (Reeves, pers. comm.)

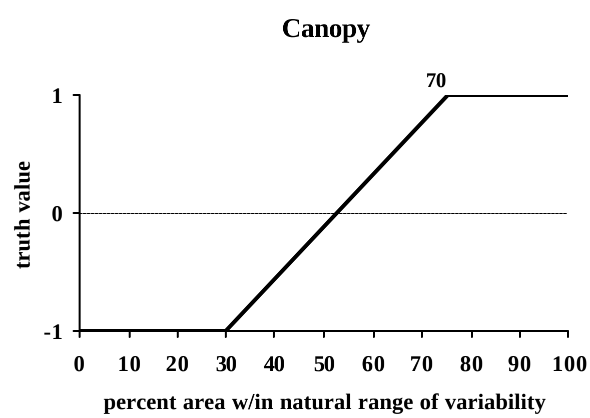

Figure 16. Breakpoints for Canopy

Early Seral

Proposition:
The total percentage area of early seral openings in the uplands of the watershed is suitable for sustaining healthy populations of native salmonids.

Definition:
Early Seral Openings is percentage area of the watershed that is in early seral conditions. These areas are where a stand-replacing disturbance has occurred, due to natural or human causes, within the past 10 years.

Explanation:
The amount of a watershed in early seral stages indicates the degree to which it has been affected by recent timber harvesting and/or stand replacing fires. In general, the larger the portion of the watershed in early seral conditions, the less likely it is to be suitable for sustaining native salmonid populations, due to higher yields of fine sediments to streams and additional heat loading of runoff.

While there is some redundancy with the Canopy parameter, the early seral openings parameter focuses on perhaps the most important seral condition, giving it additional 'weight' in the EMDS model output.

Data Sources:
The data for this parameter are robust and relate directly to the parameter as defined:

1) GIS coverages of Timber Harvest Plans over the past 10 years;
2) GIS coverage of fire history from CDF;
3) Images from Landsat Change detection (1994-1998) for north coastal California from CDF and USFS Region 5;
4) Recent Landsat images (2000)

Reference Values:
Reeves et al. (1993) examined the relationship between percentage area in early seral conditions and salmonid species diversity in a watershed, and found a significant difference between those watersheds with more than 25% area recently logged and those with less than 25% area logged. The latter watersheds usually exhibited greater salmonid species diversity. The breakpoints in the curve for Early Seral Openings in the EMDS model were selected from the results of this study. Breakpoints values for early seral openings are: <10% = fully suitable; > 30% = fully unsuitable.

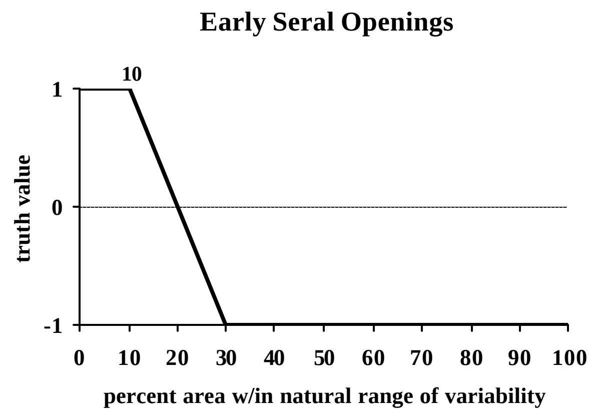

Figure 17. Breakpoints for Early Seral

Land Use

Proposition:

The percentage area of the watershed with a.) Intensive use or management; b.) Episodic human disturbance (e.g. timber harvesting) and c.) Lower impact management, is suitable for sustaining healthy populations of native salmonids.

Definition:

The Land Use is the weighed sum of two parameters:

Land Use on Stable Slopes
Land Use on Unstable Slopes

Explanation:

Stable and unstable slopes are to be defined by DOC Mines and Geology GIS coverages being created for NCWAP. Aside from the split by slope (steep vs. shallow) and corresponding differences in weighting, the two Land Use parameters are defined identically and will be treated as one for the purposes of the discussions below. In the current model, Land Use on unstable slopes was given *three times* the weight of that on stable slopes, reflecting the general expert opinion on the respective magnitudes of disturbance in the watershed (Jameson and Spittler 1995).

All of the former are weighted according to intensity of activity, time since event, and slope stability.

Reference Values:

Land Use values in a given hydrologic unit are normalized, with breakpoints empirically defined as: < 10^{th} percentile is fully suitable; > 90^{th} percentile is fully unsuitable.

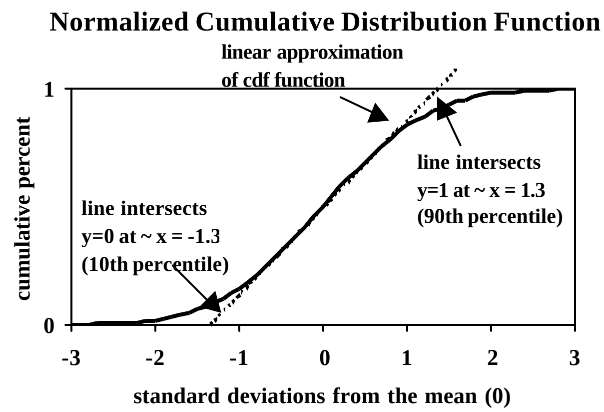

Figure 19. Using the 10th and 90th percentiles as breakpoints (as with Land Use) is a linear approximation of the central part of the normalized cumulative distribution function

Intensive Land Use

Definition:

The sum of percentages of the watershed that is “Developed Area ” and “Farmed Area”.

Explanation:

Developed areas are those that are urbanized or with clusters of buildings. Farmed areas are those with irrigated crops. This level of land use can create local hydrologic impacts such as high and short duration peak flows, which can cause more erosion and higher stream sediment loads. The combined effects are generally detrimental to the ability of the stream to support native salmonids.

With a few notable exceptions, little of the land in north coast watersheds is developed, and therefore developed areas are in general unlikely to have much influence on the model results (Botkin et al., 1995). This is also true for intensively cultivated areas. Only a few north coast watersheds (e.g. the Scott River, Lower Eel River, Middle Fork Eel) have a significant percentage of land under cultivation.

Table 1. Model weights for Intensive Land Use

Land Use	*Weights*
Developed Area	1.0
Farmed Area	1.0

Data Sources:

A GIS coverage from Region 5 of the US Forest Service of current vegetation; County parcel coverages; (For slope: DOC Mines and Geology land stability coverage (or SHALSTAB as an interim proxy))

Episodic Human Disturbance

<u>Definition</u>:

Episodic human disturbance is the percentage area affected by tractor-logging activities, weighted according to time of harvest (recent vs. historic) and slope stability.

<u>Explanation</u>:

Time breakdowns were proposed by Walker based upon expert opinion of others. Weights were approximated using information from Jameson and Spittler, inferred by Walker. Tractor logging has been broken into 5 eras (see table below).

Table 2. Model weights of eras of human disturbance

Period	*Years*	*Reasoning*	*Weights and Functions**
Recent	<=2.5YBP	New Harvests and activities	y=1.0
Era0	YBP>2.5 to 1990	Digitized Timber Harvest Plans available; last 10 or so years of management still strongly affect current processes	0.4<=y<=1.0 $y=2.088x^{-0.7379}$ (y=0.6)
Era1	1973-1990	Era post implementation of Forest Practice Rules (FPR); also coincides with start of digital Landsat data enabling high quality change detection	0.2<=y<=0.4 $y=2.088x^{-0.7379}$ (y=0.3)
Era2	1945-1973	Main era of tractor logging before FPR; main era of aerial photograph record	0.3<=y<=0.6** y = -0.0085x + 0.8047 (y=0.5)
Era3	Prior to 1945	Prior to peak of tractor logging	0.025<=y<=0 y = -0.0019x + 0.2123 (y=0.01)

*x is Years Before Present; in () is single value weight approximation for era

The above breakdowns based on time (and the weighting functions) are an effort to reflect the different magnitudes of disturbance relating to predominant timber harvesting practices, and the time since harvesting according to those practices occurred. They are based largely upon a distillation of the opinions of experts such as Marc Jameson (CDF) and Tom Spittler (DOC/DMG) (Jameson and Spittler 1995). Other breakdowns are possible, such as those which coincide with major natural disturbance events including large floods and fires.

In the first version of the model, we will use the constants (in parentheses in the above table) for each respective era of timber harvest. With more time and resources, we will use the functions shown in the table, based upon years elapsed since the event(s).

<u>Data Sources</u>:

Digitized Timber Harvest Plans
Landsat data (MSS change detection) (used to develop GIS coverages)
Aerial Photographs (used to develop GIS coverages)

Historic maps (as from timber companies)
Historic accounts
County parcel coverage (timber company holdings)
For slope DOC Mines and Geology land stability coverage (or SHALSTAB as an interim proxy)

Lower Impact Management

Definition:
The percentage of the watershed that is managed for extensive land use activities, mainly livestock grazing.

Explanation:
Extensive land use areas are primarily those that are used for livestock grazing. Grazed areas can increase delivery of sediment to streams from effects such as soil disturbance from trampling and from vegetation removal. These generally decrease the ability of the stream to support native salmonids. The effects of grazing, when not in the riparian zone (i.e. in the upland), are believed to be generally less impacting than those of timber harvesting and more intensive land uses. This is reflected in the proposed weighting for this parameter.

Table 3. Model weight of Lower Impact Management

Land Use	*Weight*
Livestock grazing	0.5

Data Sources:
US Forest Service coverage of current vegetation
County parcel coverages
For slope: DOC Mines and Geology land stability coverage (or SHALSTAB as an interim proxy)

Slope Stability

Proposition:
The percentage area of the upland watershed with unstable slopes is suitable to sustain healthy populations of native salmonids.

Definition:
(Need definition from the California Department of Conservation, Division of Mines and Geology.)

Explanation:
The natural or background slope stability of a watershed upland has major implications for the delivery and transport of fluvial sediments. In some cases the geology may strongly inhibit the ability of native salmonids to successfully reproduce in

the watershed with any regularity. This parameter is designed to indicate when such a situation is present at the planning watershed scale.

Reference values:

(These will be provided by the California Department of Conservation, Division of Mines and Geology. Currently, values in a given hydrologic area are normalized, with breakpoints empirically defined as: <25th percentile fully suitable; >75th percentile is fully unsuitable).

Data Sources:

GIS coverages from the California Department of Conservation, Division of Mines and Geology

Digital Elevation Models (10m pixels)

If DOC/DMG's coverages are not yet available, results from the computer model SHALSTAB may serve as an interim proxy.

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